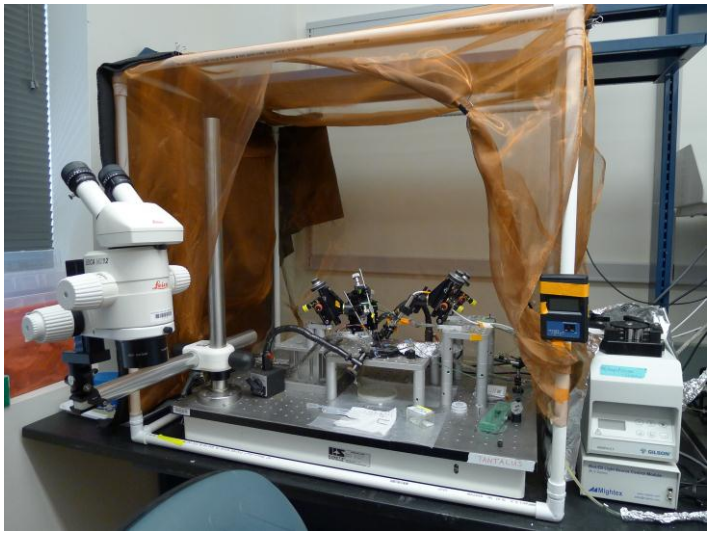
The Great Stagnation: Getting to the Next "Industrial Revolution"

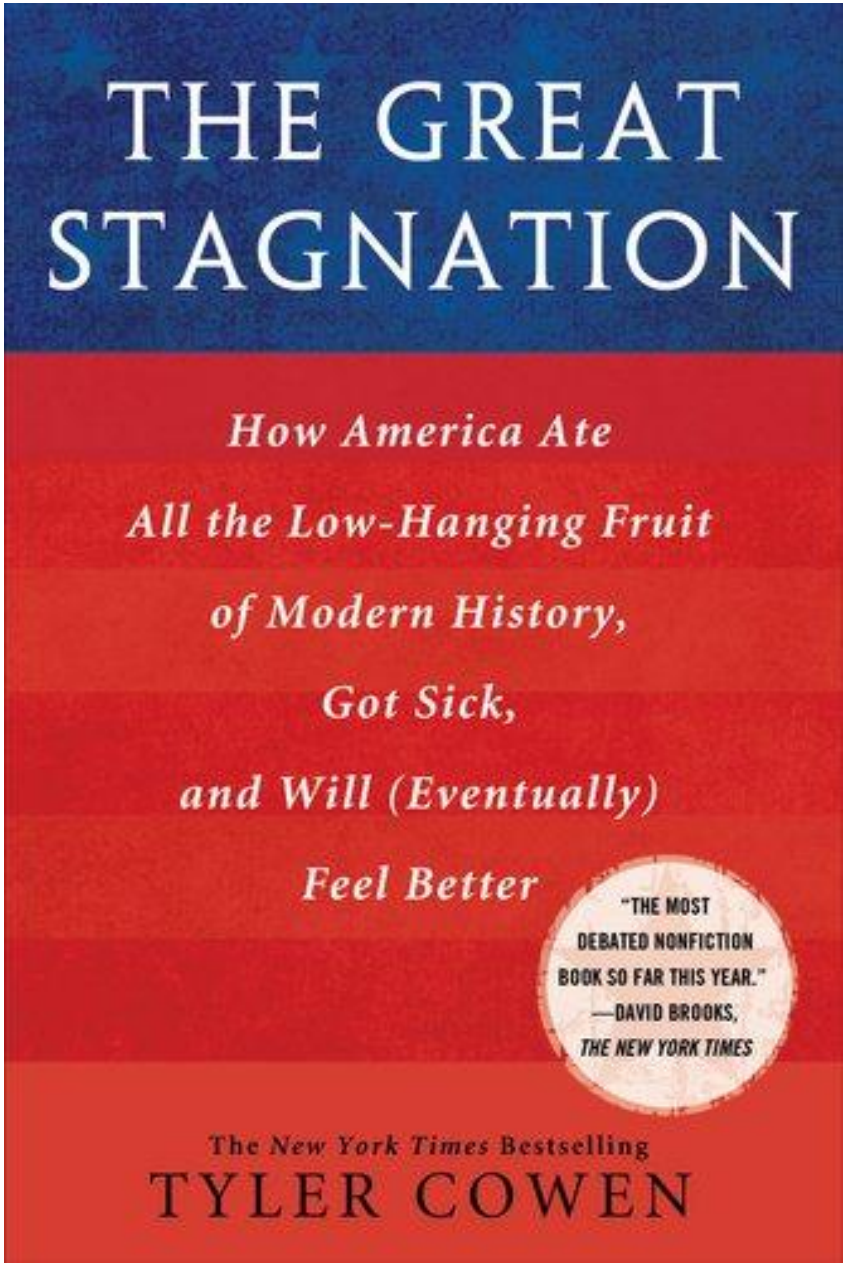
Neuro-inspired Computational Elements Workshop

Sandia National Lab Feb. 2013

Talk Outline:

- The Great Stagnation
- #BAM Project
- The Cognitive Society
- Goals for the next decade
- Infrastructure needs
- R&D strategies
- Conclusions and priorities





What do we mean by stagnation?

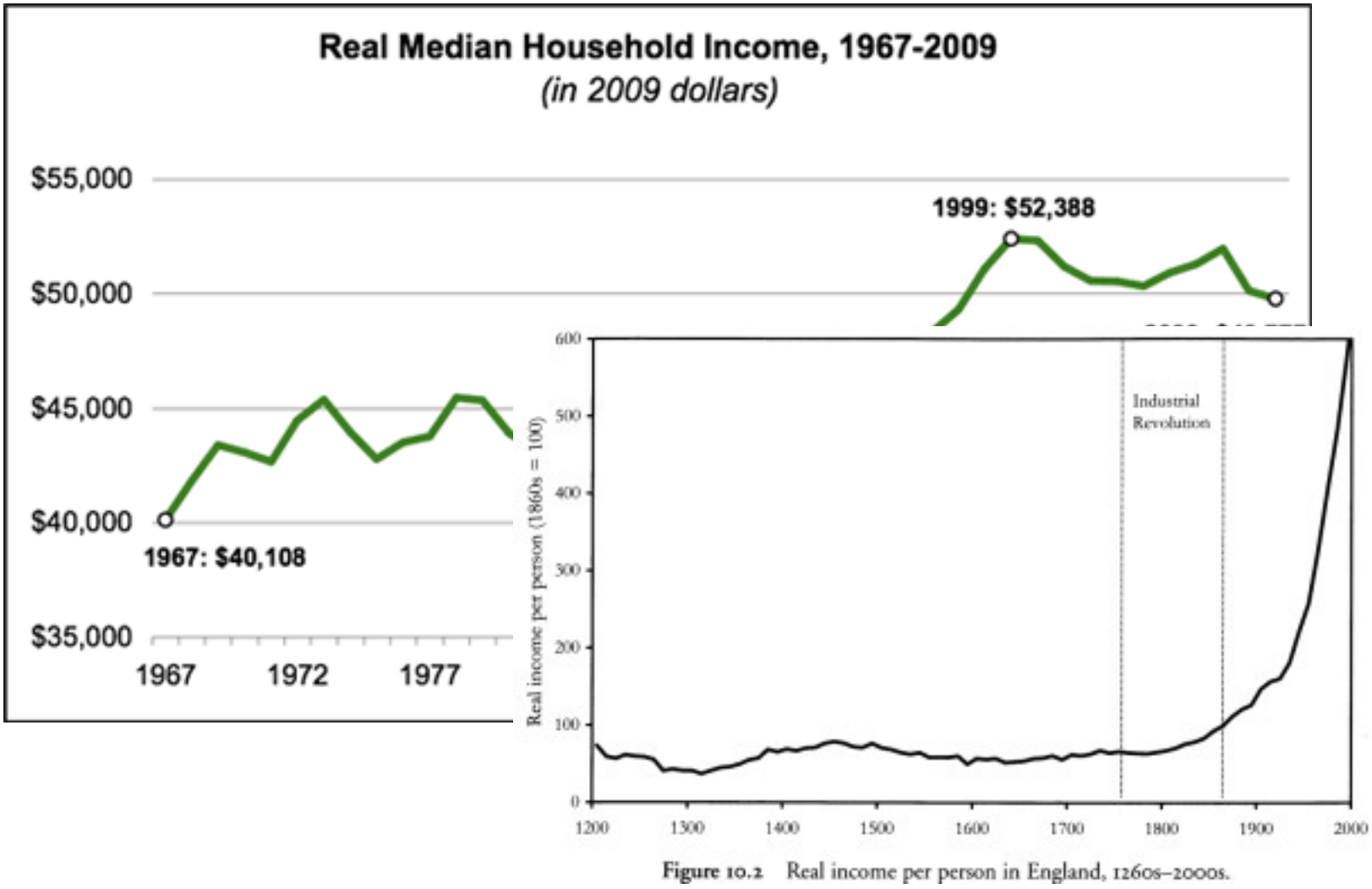
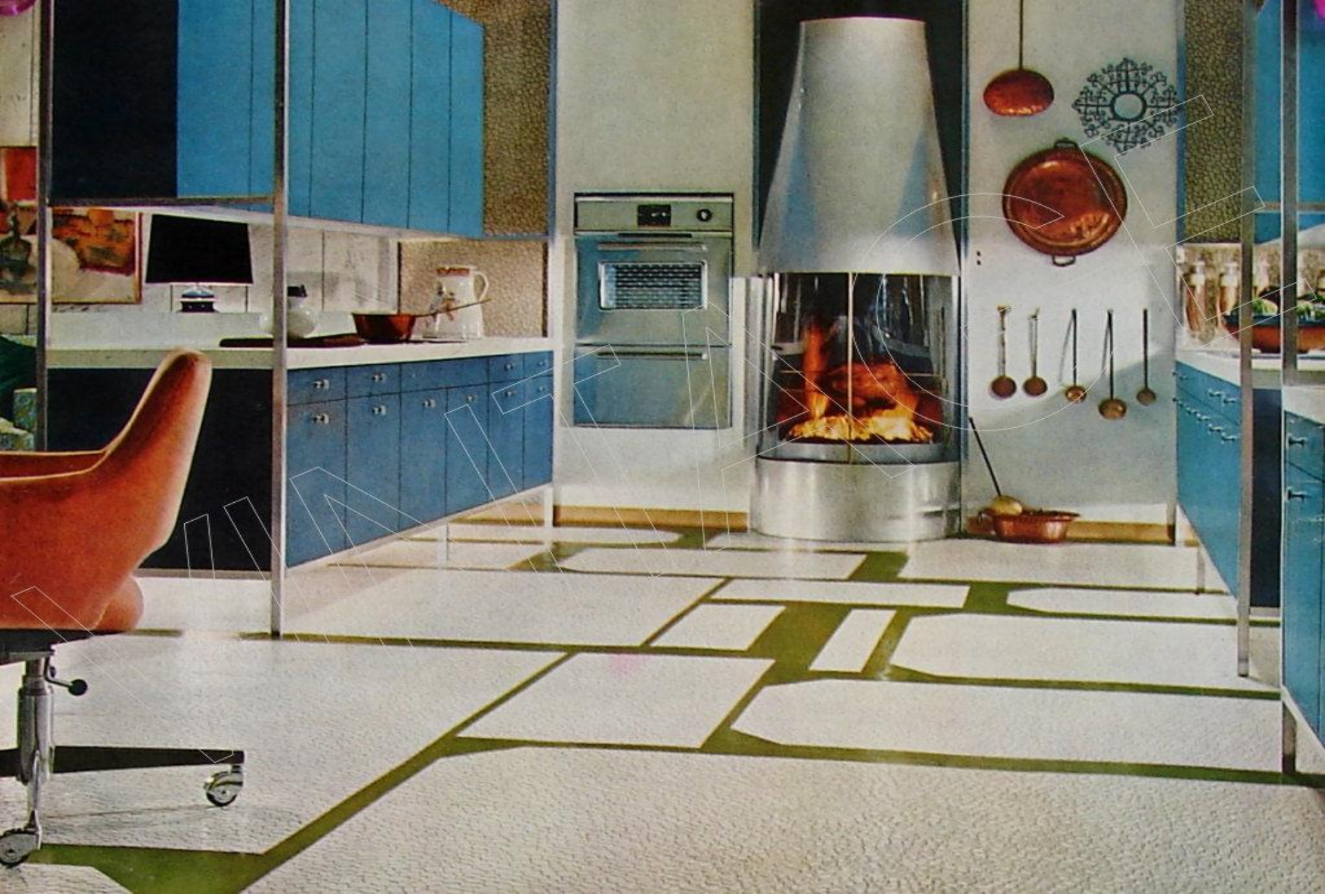
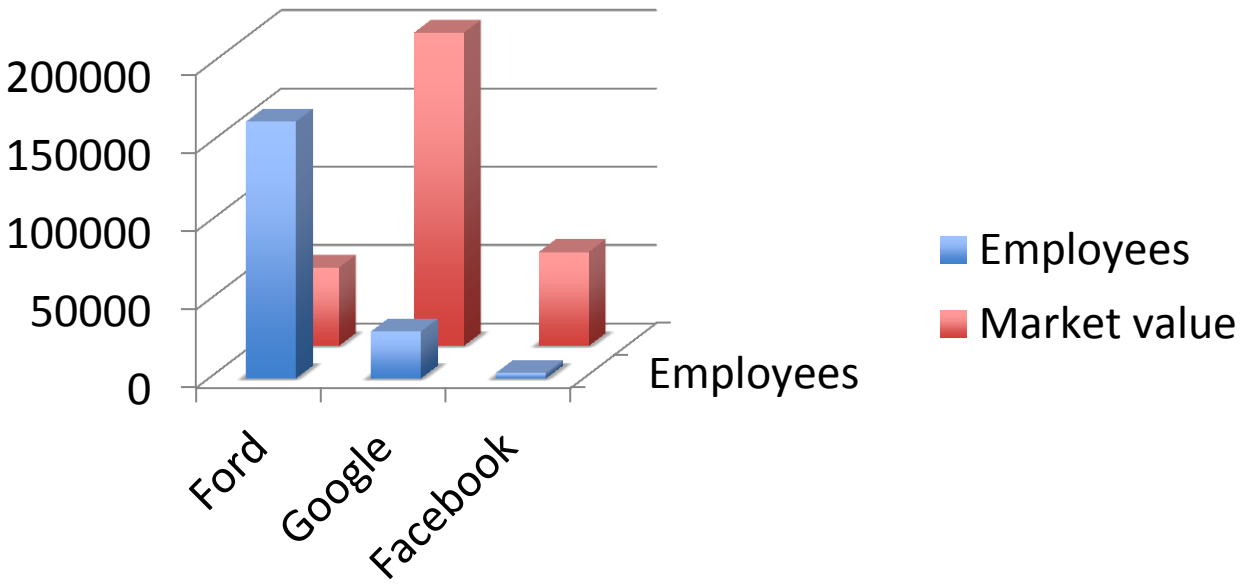


Figure 10.2 Real income per person in England, 1260s–2000s.

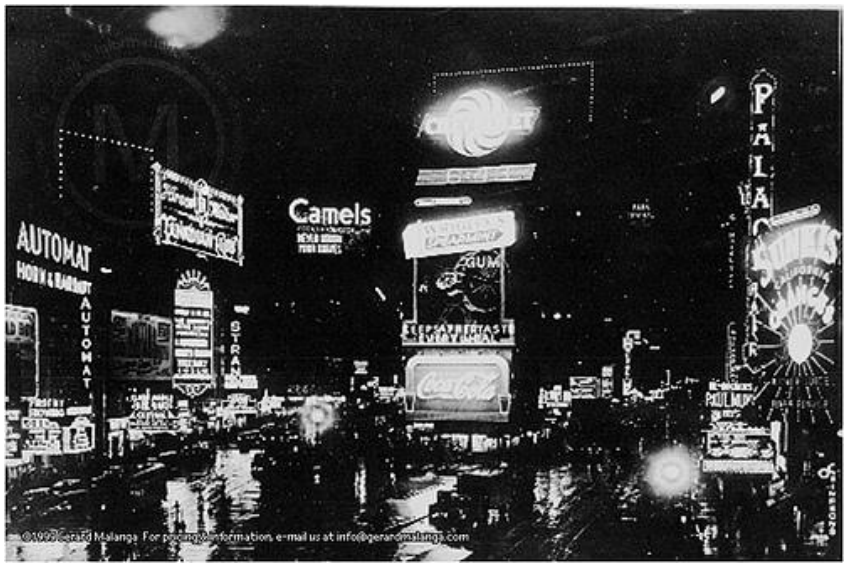


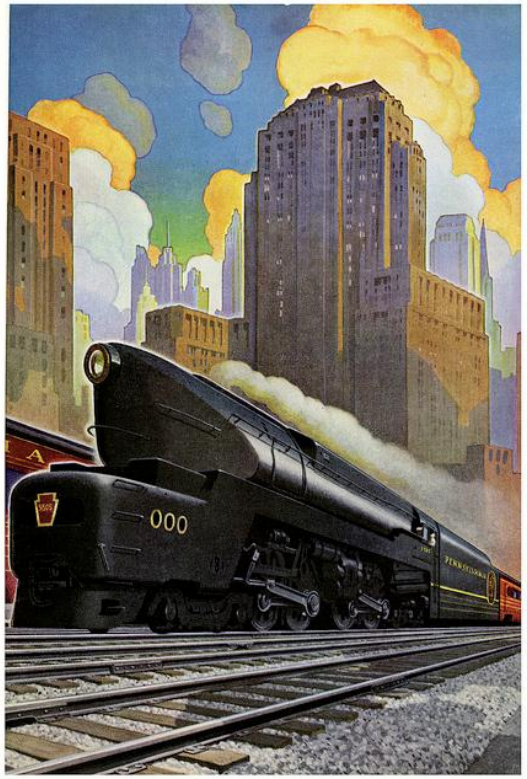
But what about the Internet and Moore's Law?

Jobs versus Market Value:



TGS Argument: Moore's Law not like the Industrial Revolution or Electricity





The New York Times

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Obama Seeking to Boost Study of Human Brain

Danny Moloshok/Reuters

Francis S. Collins, the director of the National Institutes of Health, one of the federal agencies involved in the project.

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By JOHN MARKOFF

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February 22, 2013 6:04 pm

Science: Contours of the mind

By Clive Cookson

Projects to map the brain herald a possible golden age of neuroscience

Cranium cartography: these pathways carry information between nerve cells in the cerebrum, top, and brainstem, bottom

For anyone daunted by a map of the London Underground, with nearly 300 stations on its maze of lines, it is probably best not to try to visualise a chart of the human brain.

The New York Times

The Opinion Pages

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEAL

OP-ED CONTRIBUTOR

What Our Brains Can Teach Us

By DAVID EAGLEMAN

Published: February 22, 2013

HOUSTON

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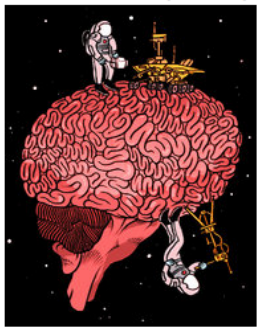

Kristina Collantes

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Opinion

AFTER President Obama's recent announcement of a plan to invigorat the study of neuroscience with what could amount to a $3 billion investment, a reasonable taxpayer might ask: Why brain science? Why now?

e map of its activity, seeking to d

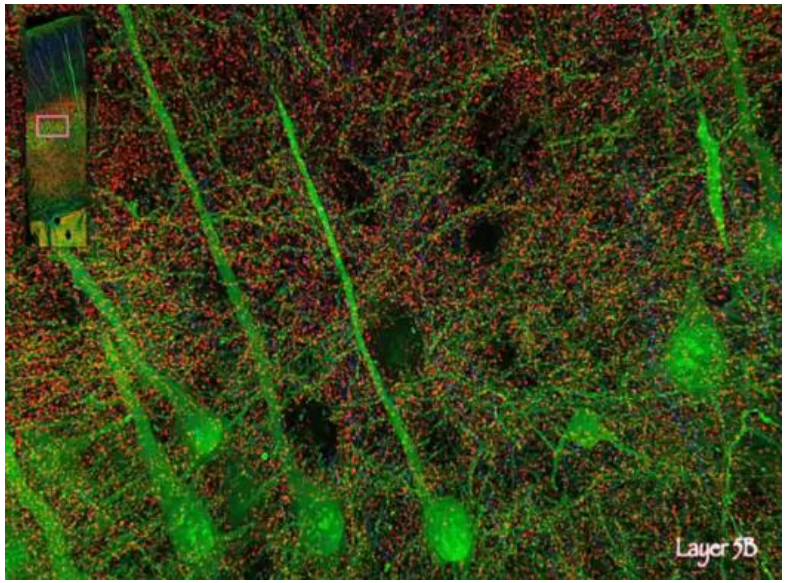
Here's why. Imagine you were an alie catching sight of the Earth. Your species knows nothing about human interpret the interactions of seven bil social networks. With no acquaintan human language or behavior, it prov decipher the secret idiom of neighbo governments, the interplay of local a the intertwining economies of nation pandemonium, a meaningless Babel.

ams of neuroscientists and nanos sness.

So it goes with the brain. We are the landscape, and the brain is an even r

BAM is really daunting—we get fooled by circuit diagrams and Golgi-staining

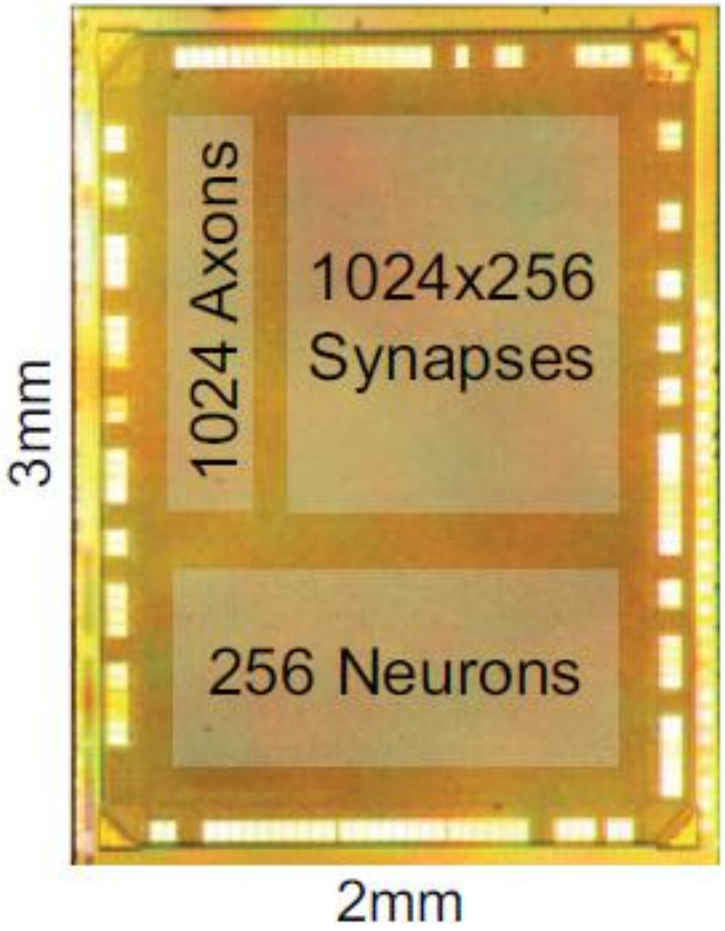
Steve Smith Movie:



Human Brains versus Digital Computers

- 10^{11} neurons x 10^{4} synapses=10^{15} computational elements
- Highly parallel
- Wet-ware (ms, µm)
- Hardware==Software, True
- Signal transduction=message passing

- Transistors: IBM Blue gene=1.5 x 10^{8}
- IBM True North: 10^{14} synapses, running 1500 times slower than brains
- Parallel non-trivial
- CMOS
- In Silico (µs, nm)
- Hardware==Software, False
- Message passing non-trivial



NeuroMorpho.Org

Krasnow Institute for Advanced Study

Version 1.0, released: 12/22/06, content: 1029 cells

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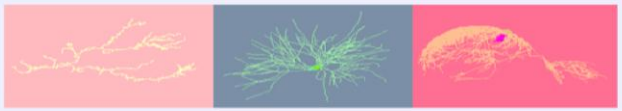
NeuroMorpho.Org is a centrally curated inventory of digitally reconstructed neurons. *NeuroMorpho.Org* contains contributions from over two-dozen labs and is continuously updated as new morphological reconstructions are collected, published, and shared, with the goal of densely covering all available data.

Morphological data are essential for understanding the cellular complexity of the nervous system, and are used for analysis, visualization, and modeling.



NeuroMorpho.Org was established to facilitate access to such data and to encourage data

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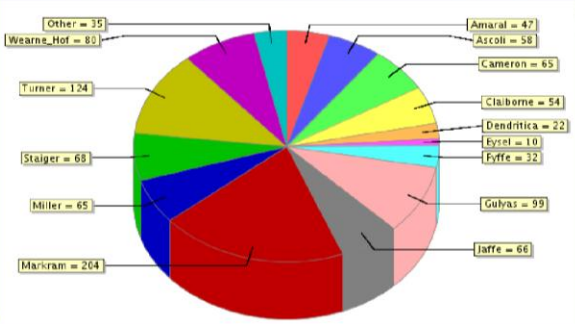
By Animal Species | By Brain Region | By Cell Type | By Lab Name



☐ **Amaral**

Rat

Hippocampus

Pyramidal cell

- ☐ c70963
- ☐ c12971
- ☐ c72965
- ☐ c12973

Go to lab: Amaral Go!

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Animal
- Species: Monkey / Macaque Monkey
- Sex
- Minimum Weight
- Maximum Weight
- Development
- Minimum Age
- Maximum Age

Experiment
- Stain: Lucifer Yellow
- Reconstruction Method
- Protocol
- Objective Type
- Objective Magnification
- Slicing Thickness
- Slicing Direction

Anatomy
- Brain Region
- Cell Type: Principal cell / Pyramidal cell / Local projecting

Source
- Archive
- Neuron Names
- Original Format
- Date of Deposition
- Date of Upload

Hits from current criteria: 20

Your search results can be arranged:

By Animal Species | By Brain Region | By Cell Type | By Lab Name

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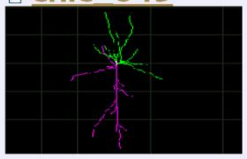
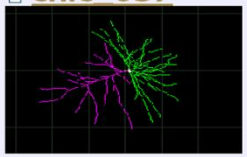
20 neurons found

☐ **cnic_049**



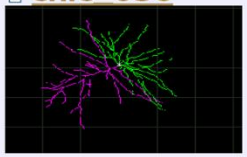
Archive Name: Wearne_Hof
Species Name: Monkey
region1: Cerebral cortex
region2: Prefrontal
Main Cell Type: Principal cell
class2: Pyramidal cell

☐ **cnic_037**



Archive Name: Wearne_Hof
Species Name: Monkey
region1: Cerebral cortex
region2: Prefrontal
Main Cell Type: Principal cell
class2: Pyramidal cell

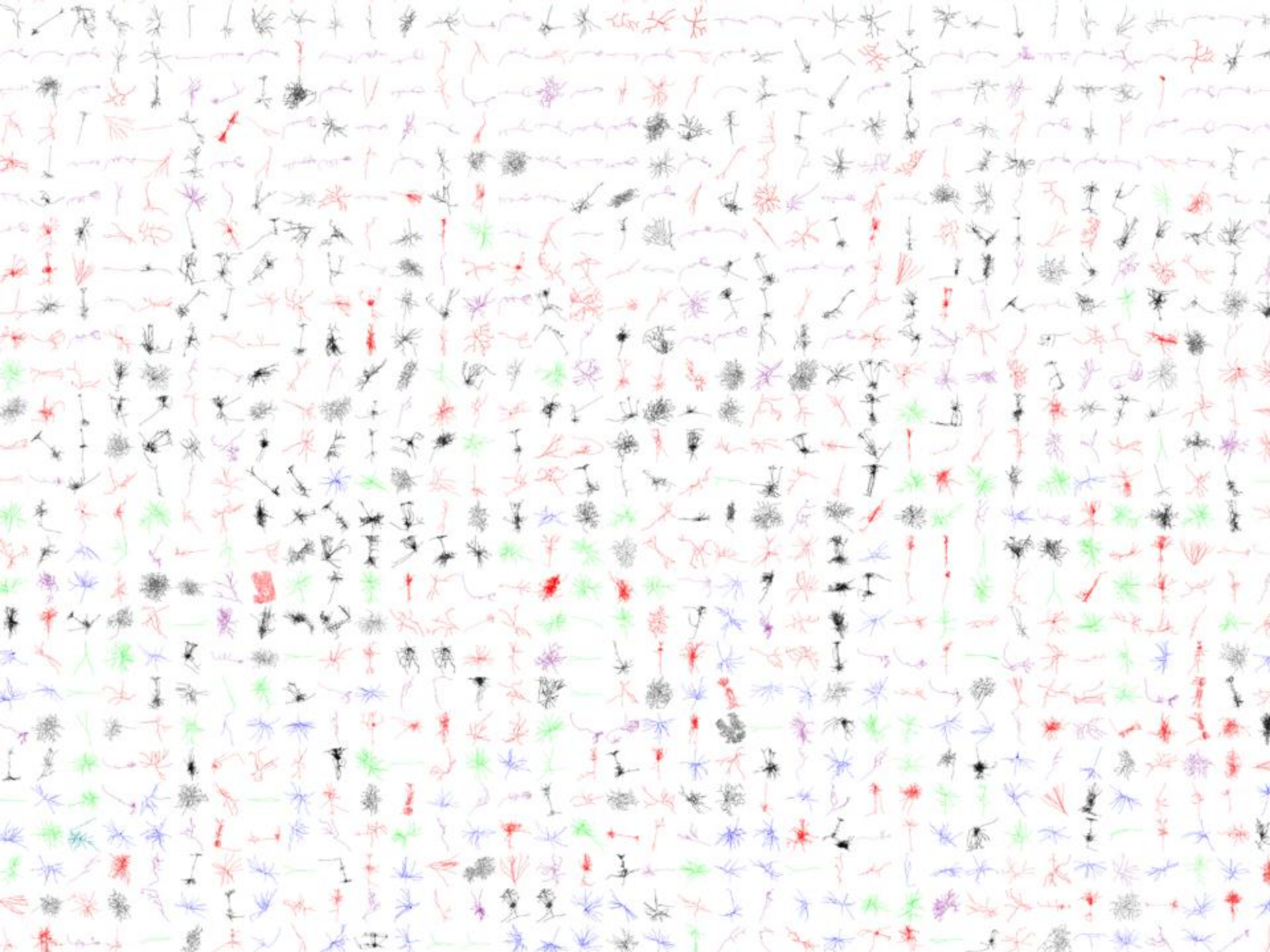
☐ **cnic_036**

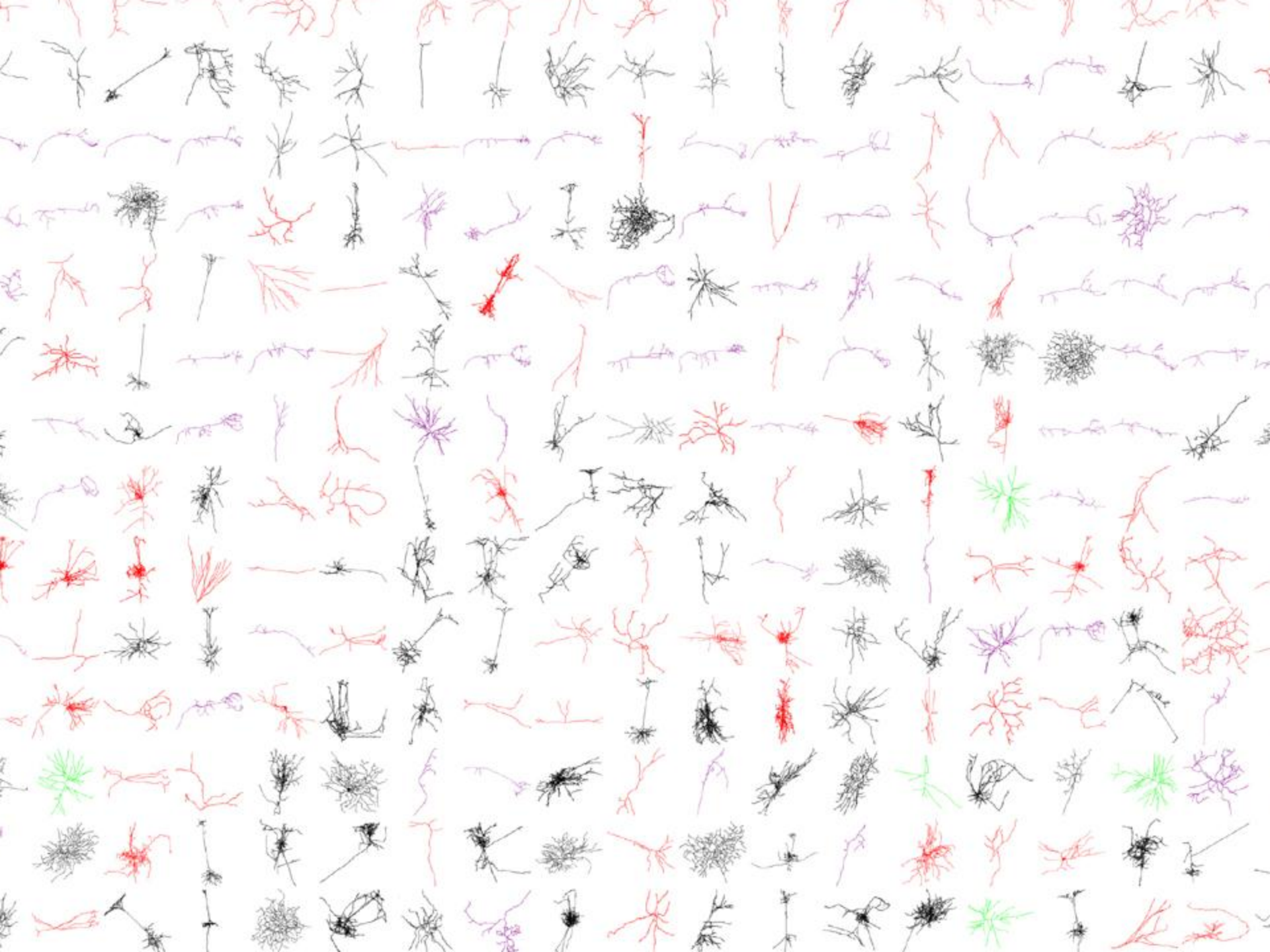


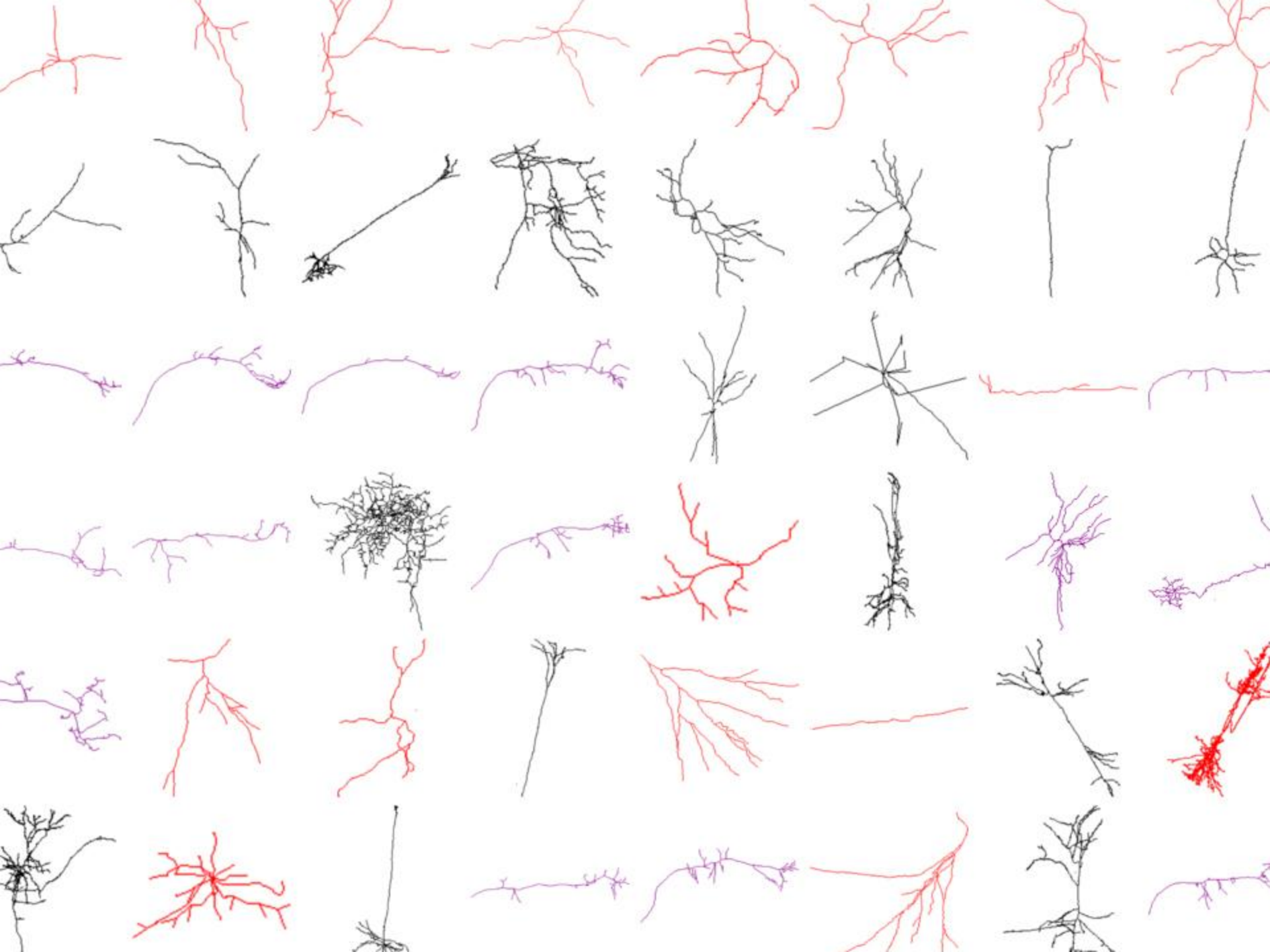
Archive Name: Wearne_Hof
Species Name: Monkey
region1: Cerebral cortex
region2: Prefrontal
Main Cell Type: Principal cell
class2: Pyramidal cell

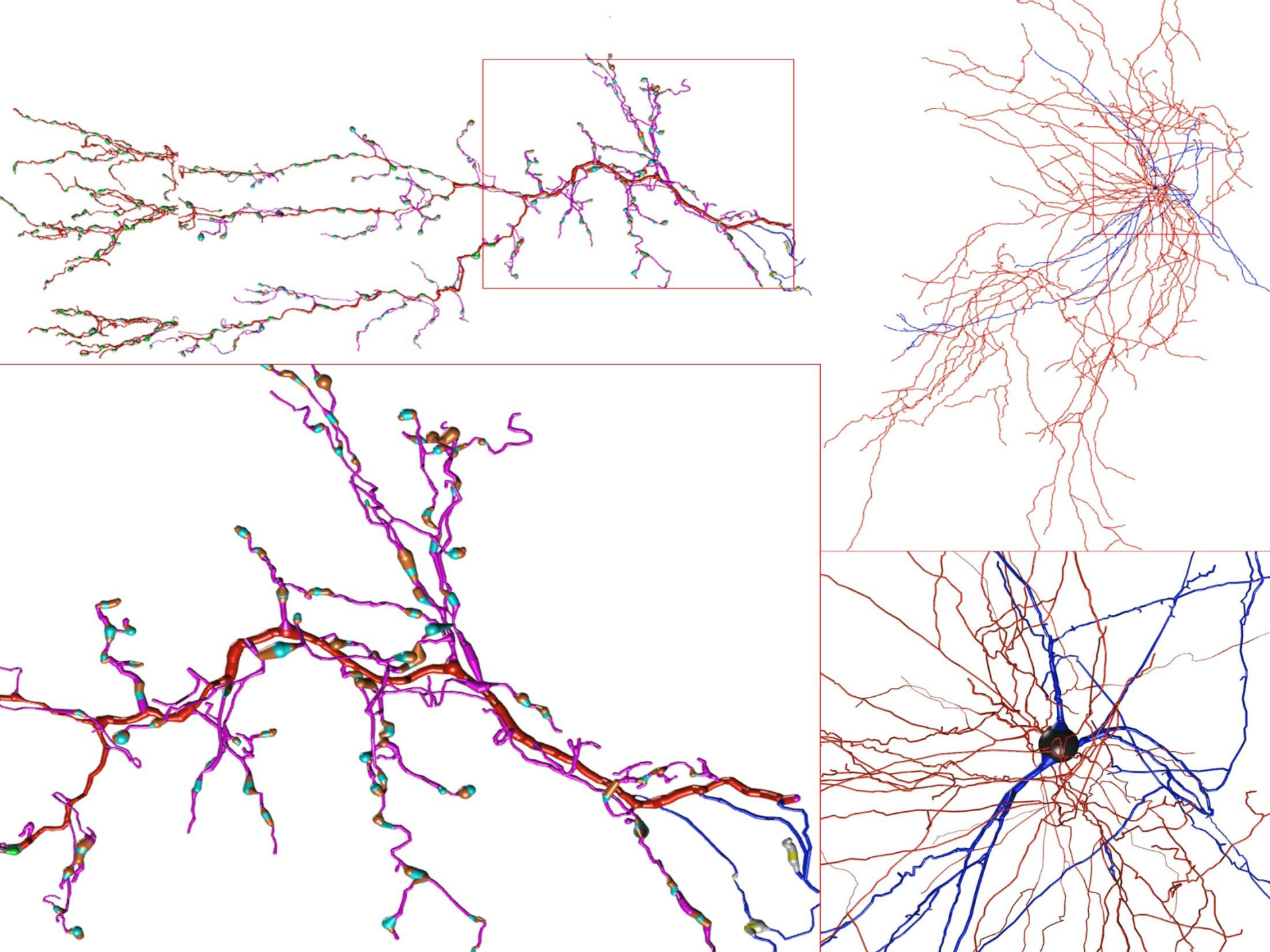
☐ **cnic_035**

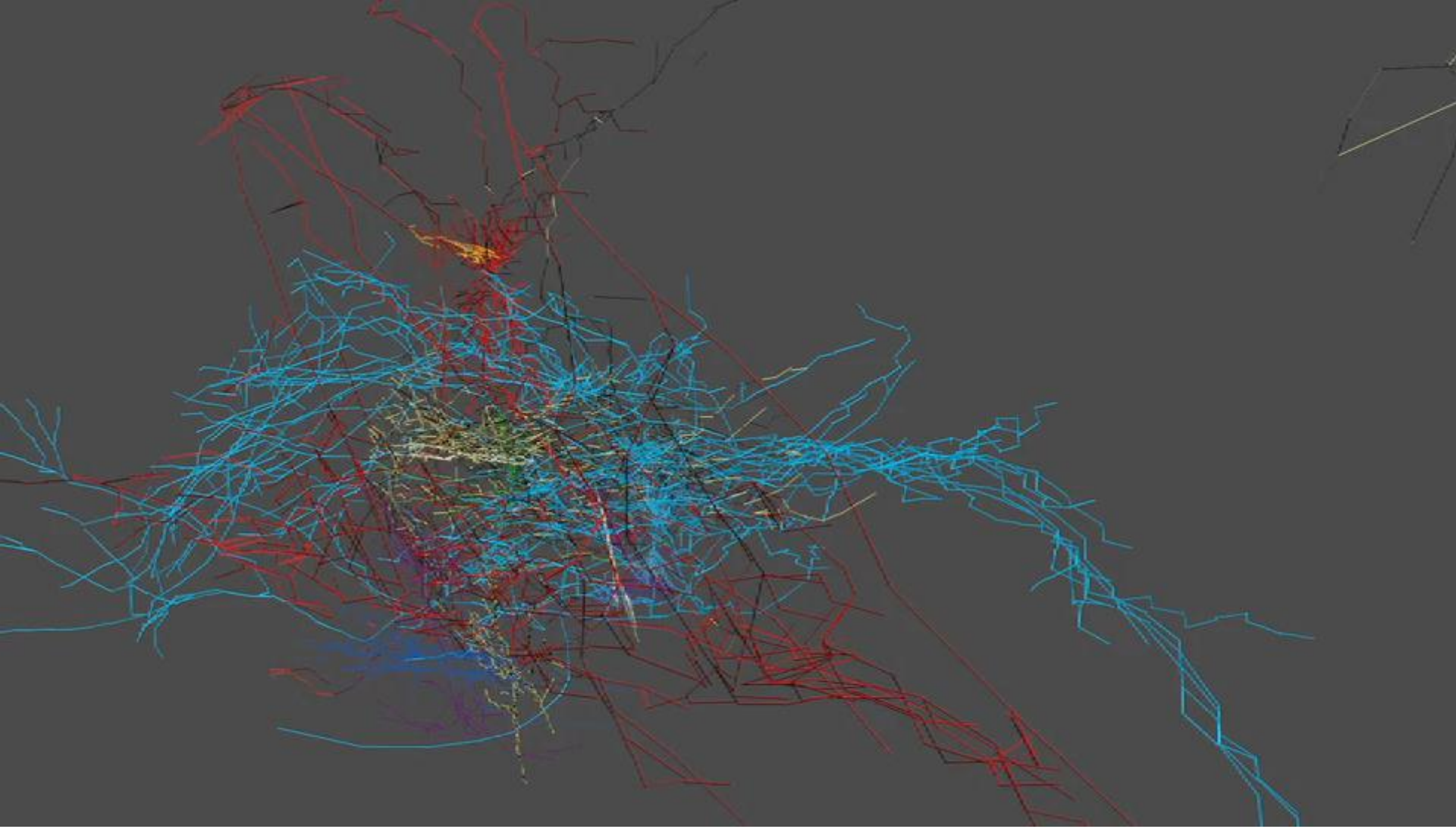
Archive Name: Wearne_Hof



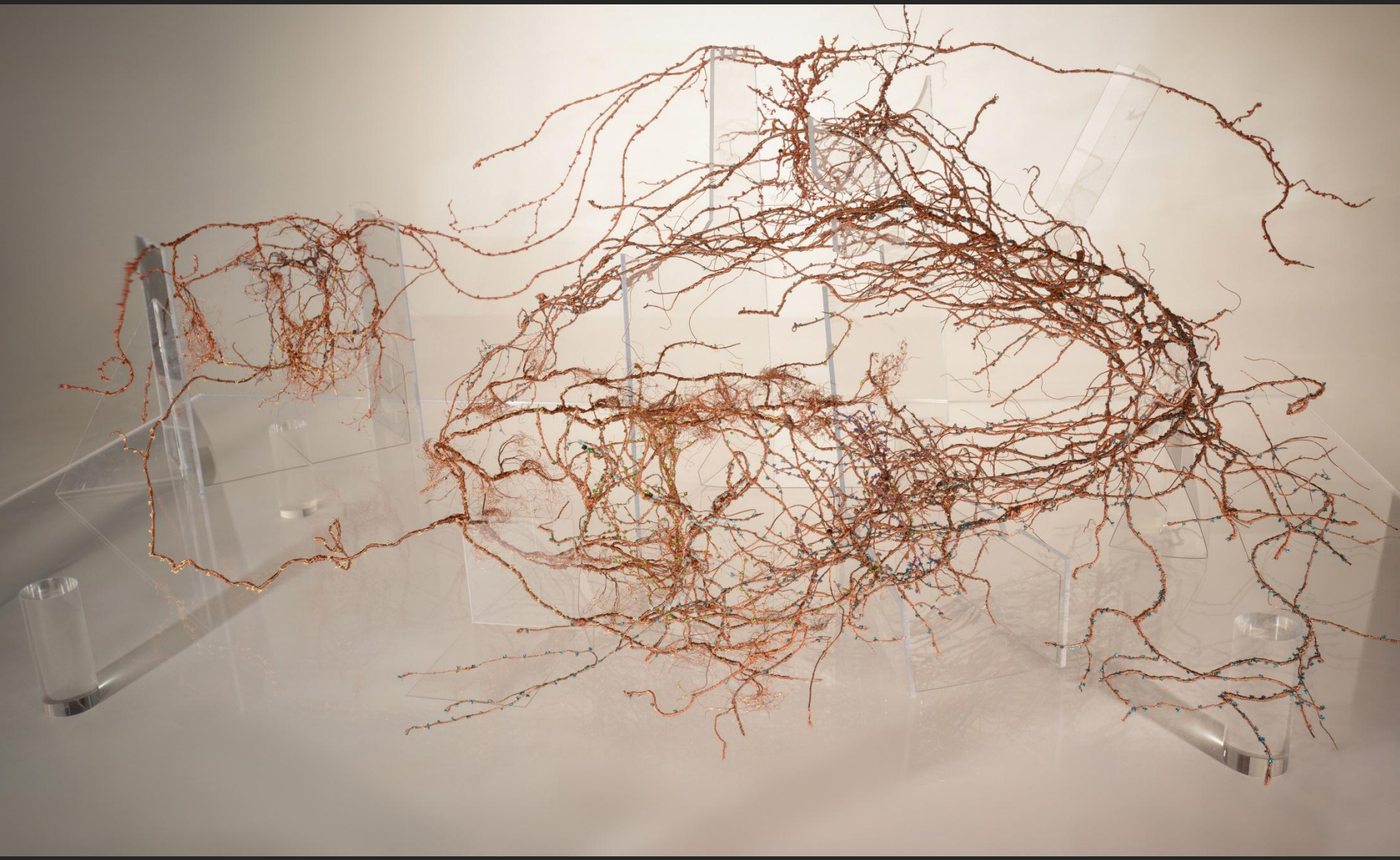








CN3 Center, Giorgio Ascoli, Krasnow Institute




MBL

What #BAM really means:

Time bins (ms)

10^{11} neurons

N1,1	N1,2	.	.	.	.	.	$N_{1,j}$
N2,2	.						
.		.					
.			.				
.				.			
.					.		
.						.	
$N_{i,1}$							$N_{i,j}$

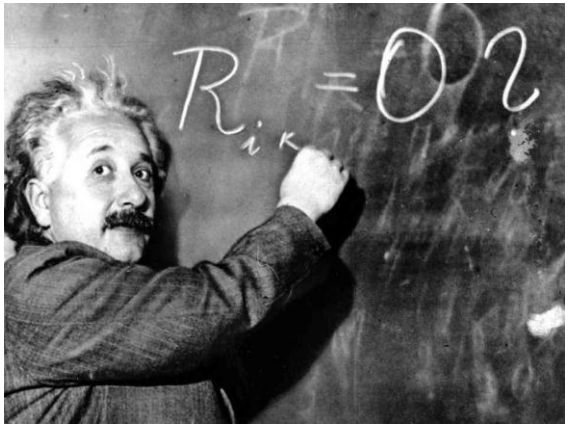
Morphological plasticity

Neurogenesis

Organization by cell assembly

The Cognitive Society:

We need a new BRAIN-inspired industrial revolution!



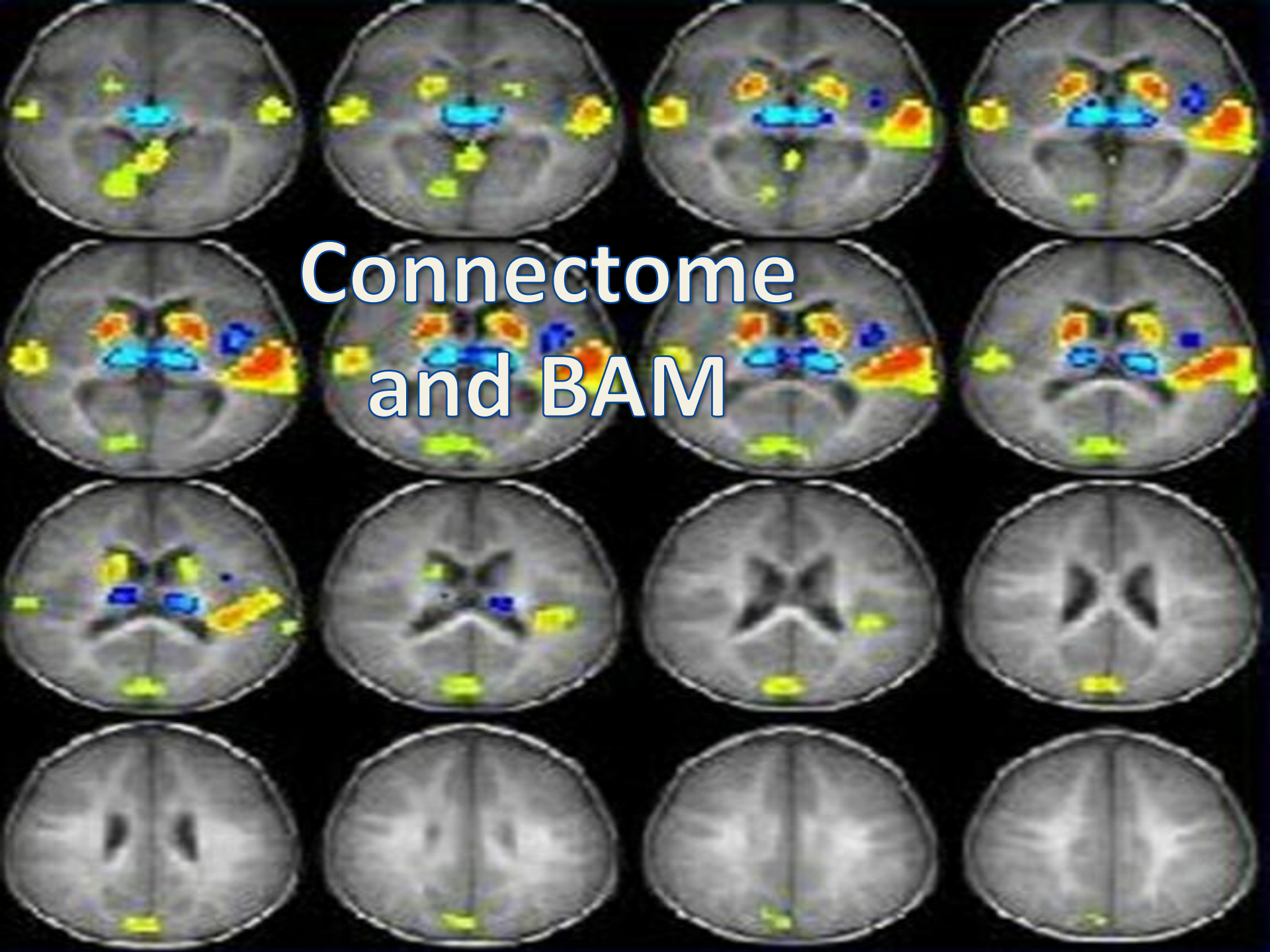
Vision: “The Cognitive Society”

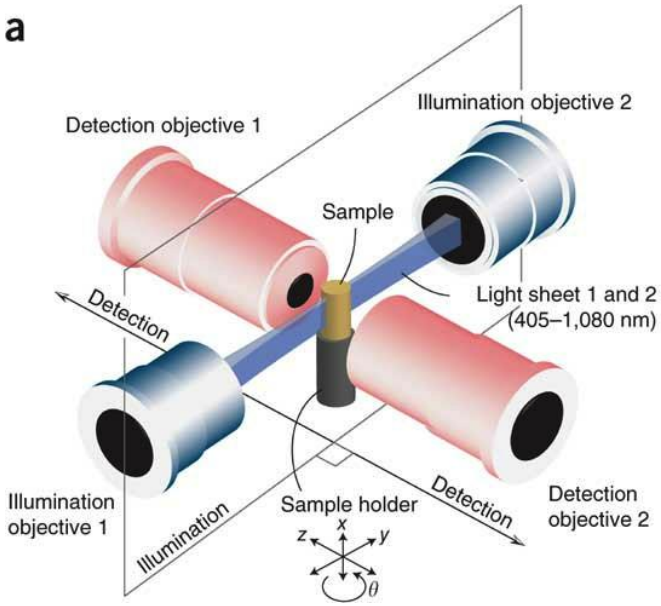
- Future global enhanced cognitive awareness
- An emergent of the current co-evolution/trajectory of multiple fields
- Beyond the notion of #BAM and Connectome to a new concept: “Cognome”— the blueprint for higher cognition (individual and social)
- Renaissance in human cognition and social communication (enhancing *Team Science*)

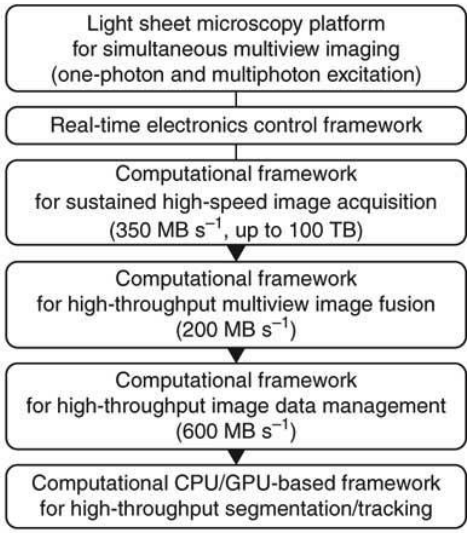
Advances in the last decade:

- NeuroX (X=econ, ethics, marketing, law etc.)
- Computing/Cloud/Social Networking
- Functional brain imaging & stimulation
- Social enabling of Big Data
- Widespread general access to “Maker” tech

Image: Christian Science Monitor


Connectome
and BAM

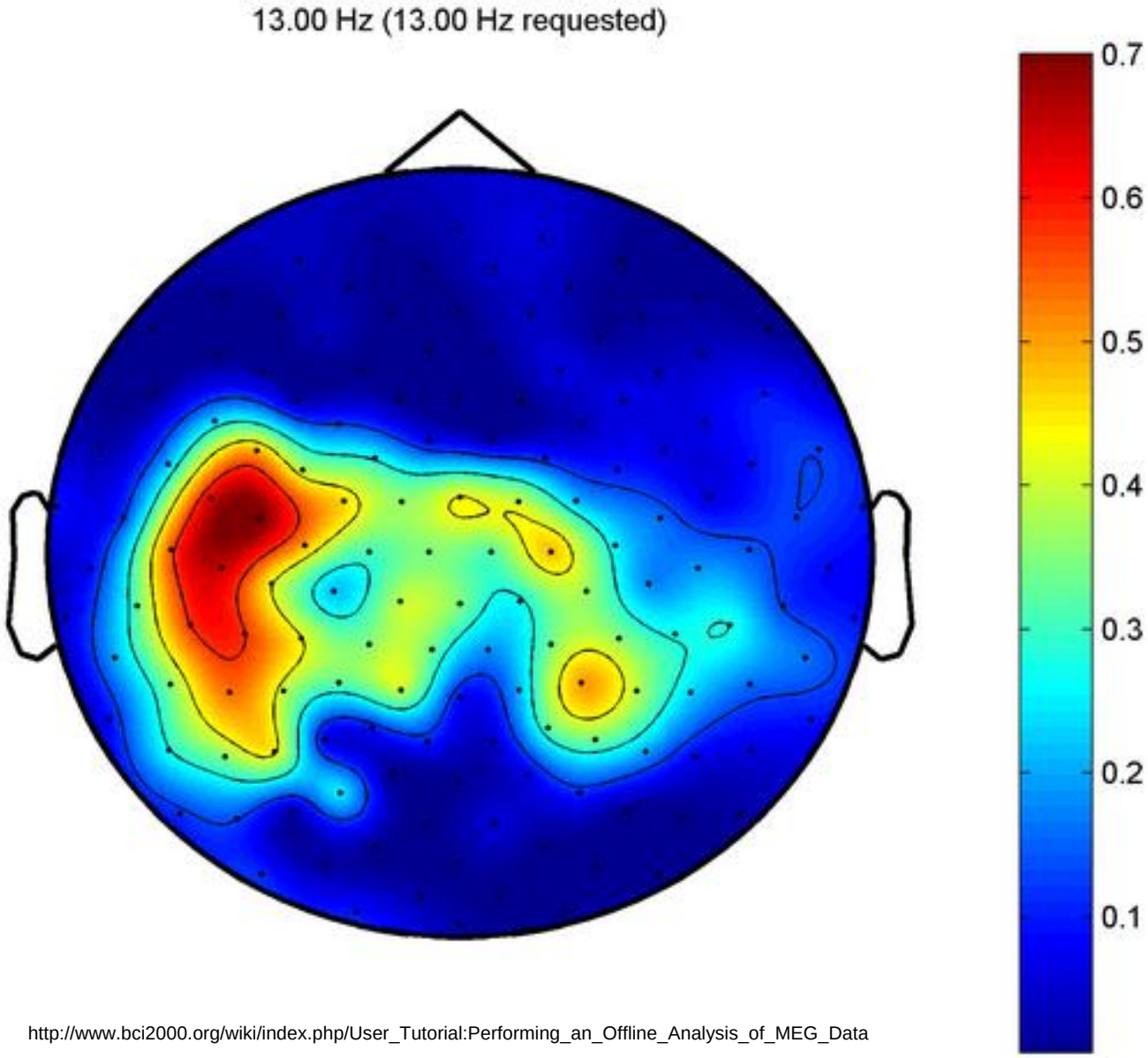




Nature Methods, Tomer et al. 2012

Keller Lab, Janelia Farm Campus HHMI

Need every cell

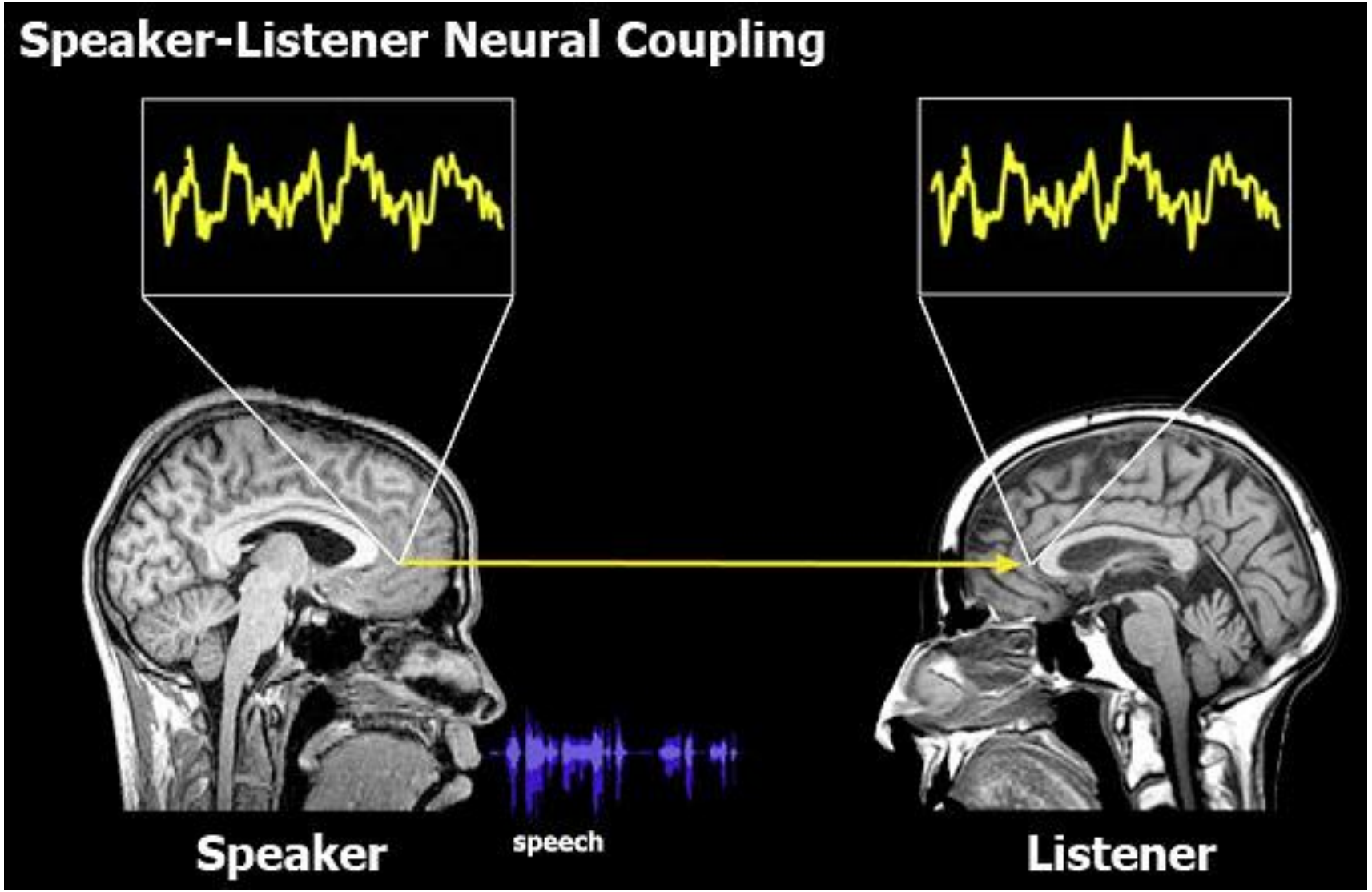


http://www.bci2000.org/wiki/index.php/User_Tutorial:Performing_an_Offline_Analysis_of_MEG_Data

http://www.onepennysheet.com/2010/03/the-worlds-first-commercial-brain-computer-interface-and-the-history-of-bci/

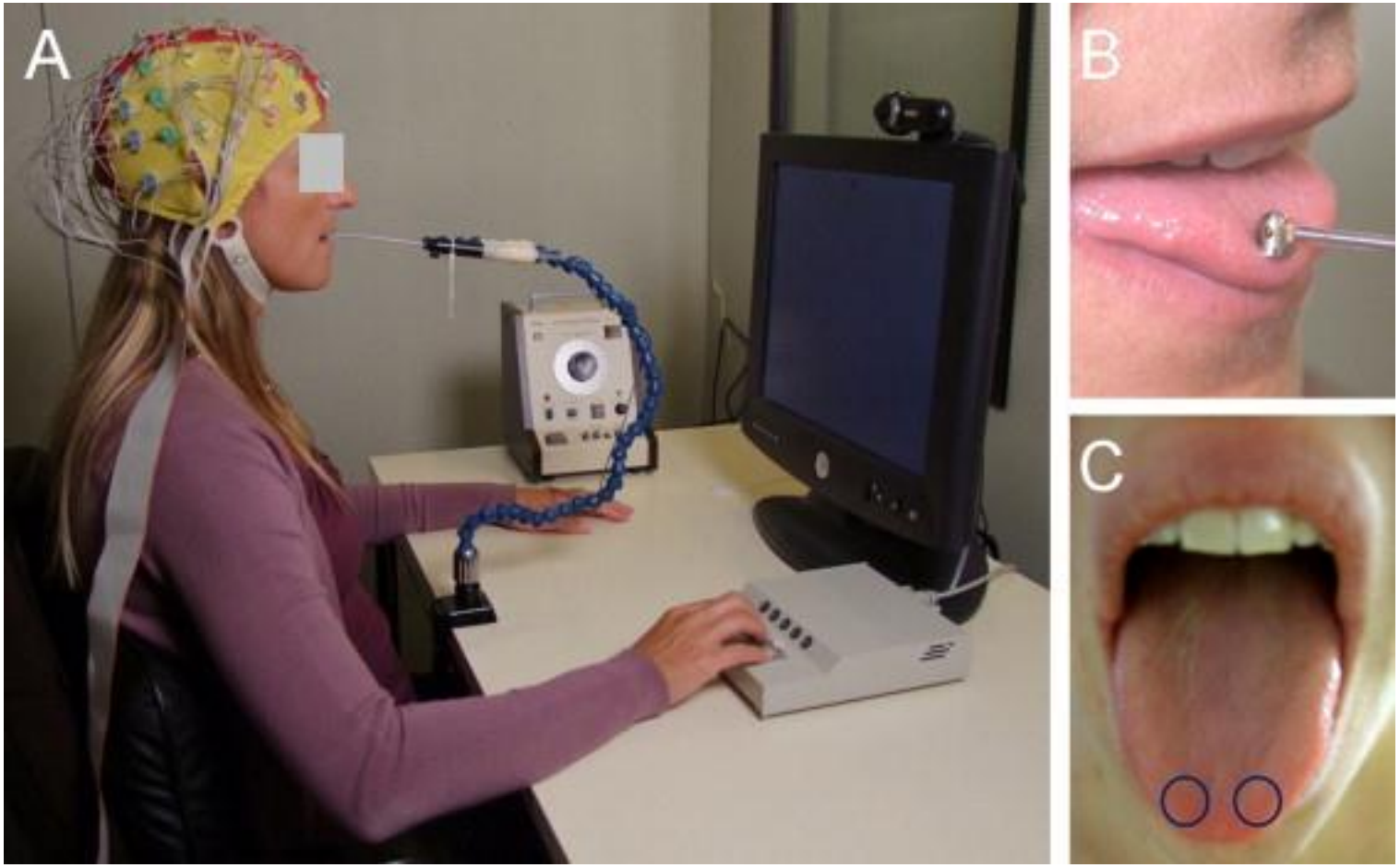
http://www.bbisf.com/brainwave.html

Global Cognitive Awareness:



Uri Hasson Lab, Princeton

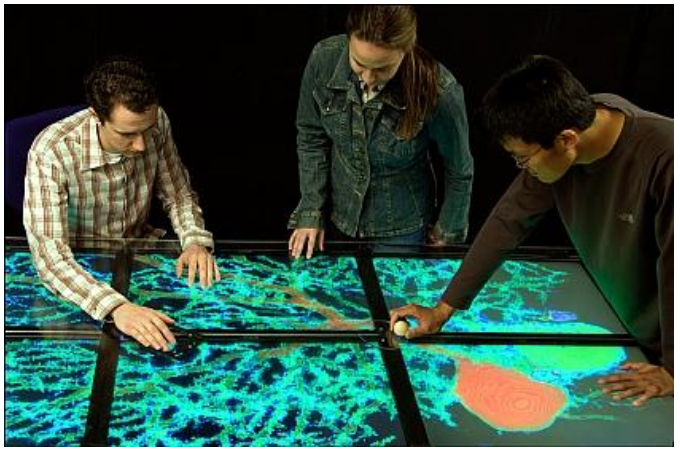
Sensory channels reprogrammed:



http://dx.doi.org/10.1016/j.biopsycho.2010.09.007

Cognitive science of science:

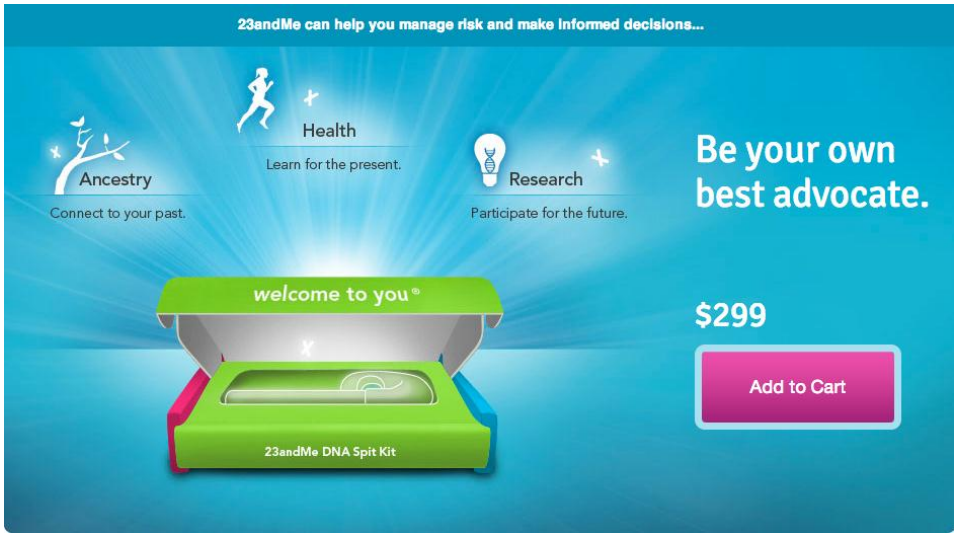
- Better designs for science tools
- Improved education for future scientists
- Insights to help science *teams*
- New principles for convergence between sciences



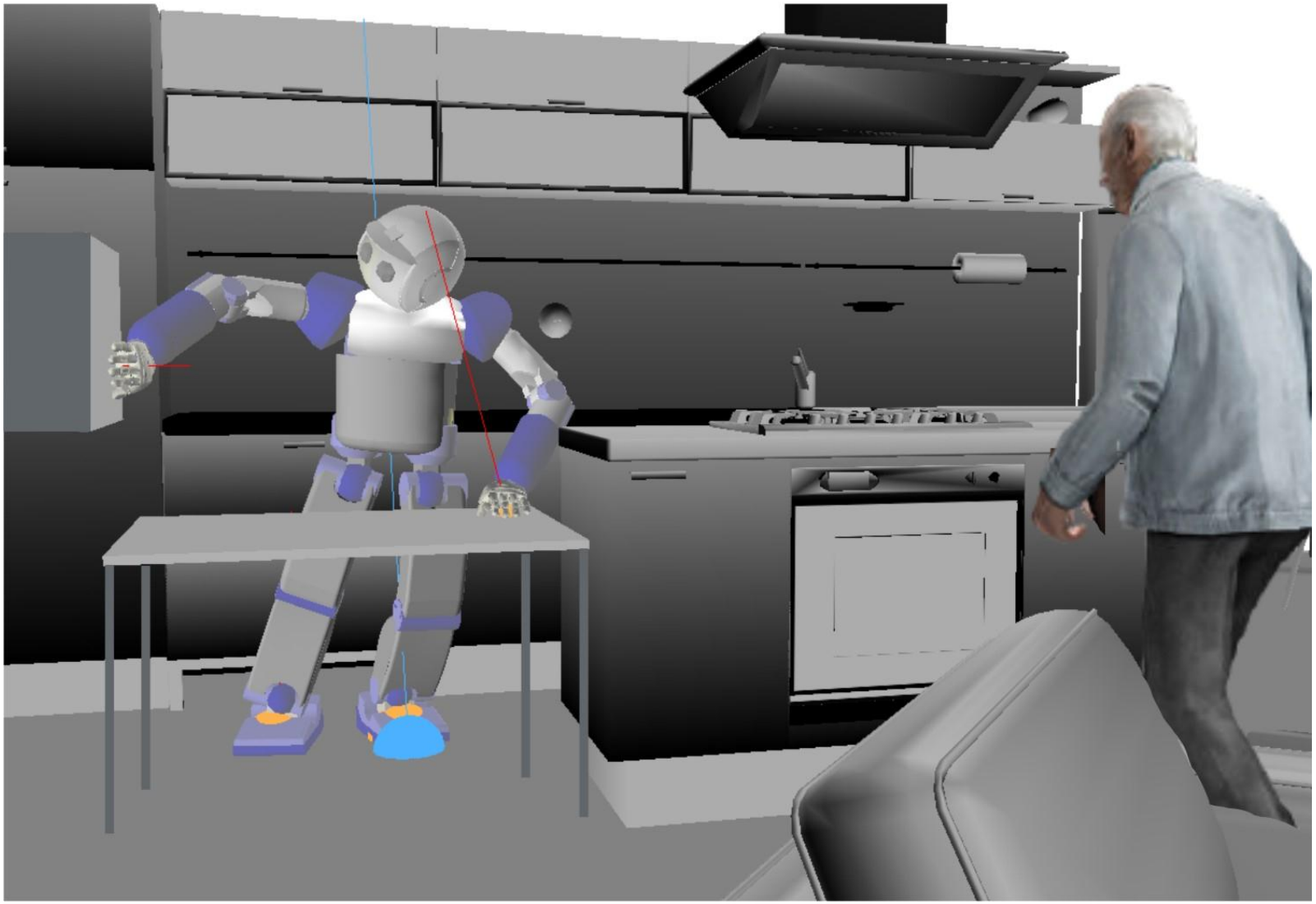
http://www.scidacreview.org/0902/html/optiputer.html

Goals for next decade:

- Robotic Tech for Cognitive and Social Support
- Cognome
  - E.g. Using plasticity to heal brain diseases
- Personalized access to “omics”
- National reinvention

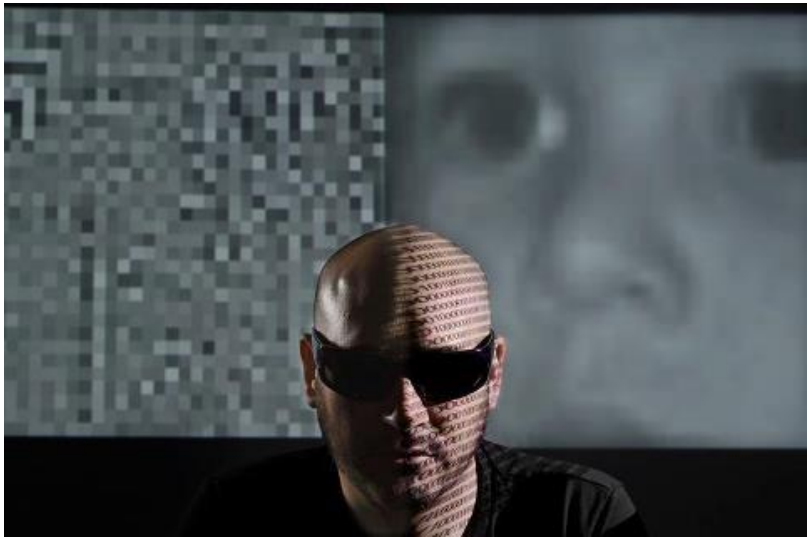


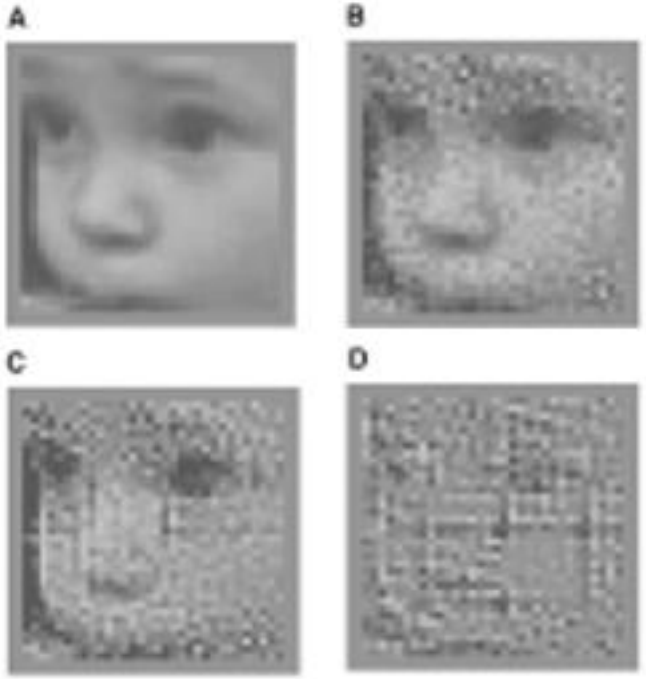
Robots to enhance “senior” life:



Sentis Lab: UT Austin

Nirenberg retina:





http://www.cyberpunkworld.com/artificial-retina-uses-brain-communication-code-to-restore-vision/

https://www.facebook.com/photo.php?fbid=426671604048178&set=a.411488402233165.88598.394690573912948&type=1&theater

“My own genomics”

“It’s time to lead again…”
National Reinvention

- Enhance the range of productivity to include retirement years
- Increase levels of safety and security so that normal decline of physical and mental abilities is lessened
- Improve methods of wealth development leveraging Moore’s Law
- Develop enhanced modeling of societies to keep life meaningful

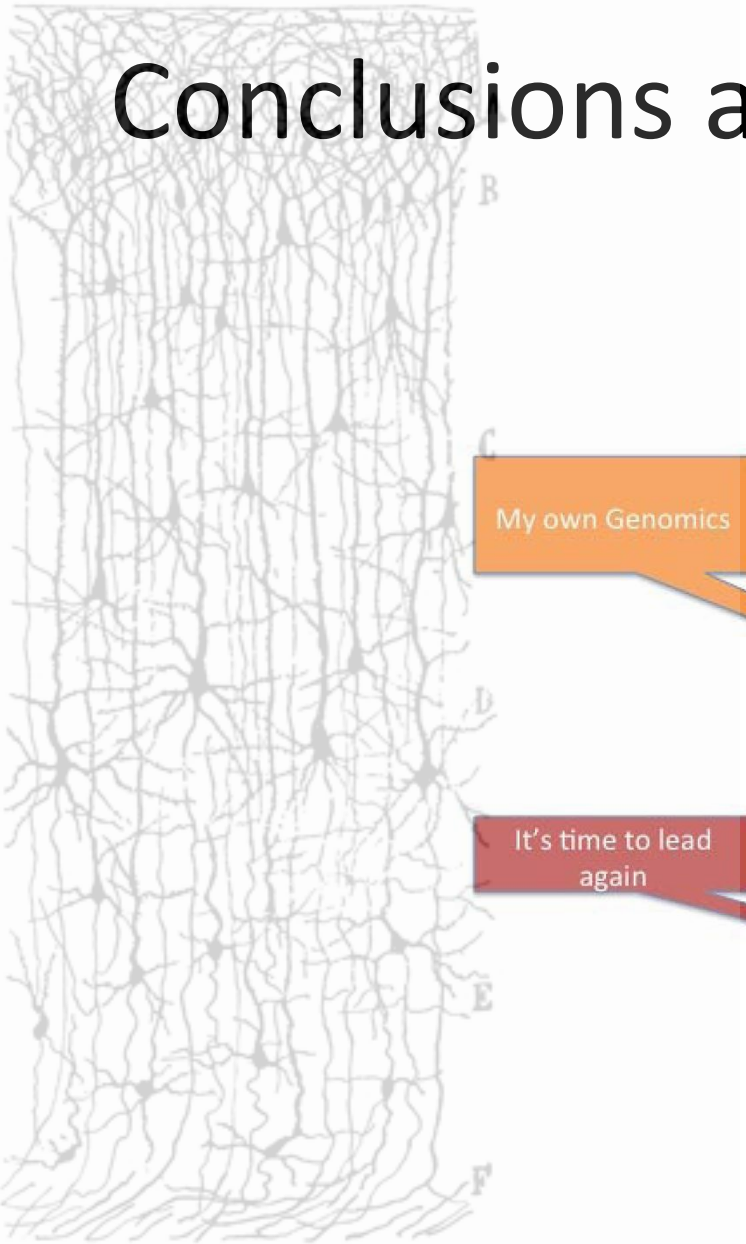
Infrastructure needs:

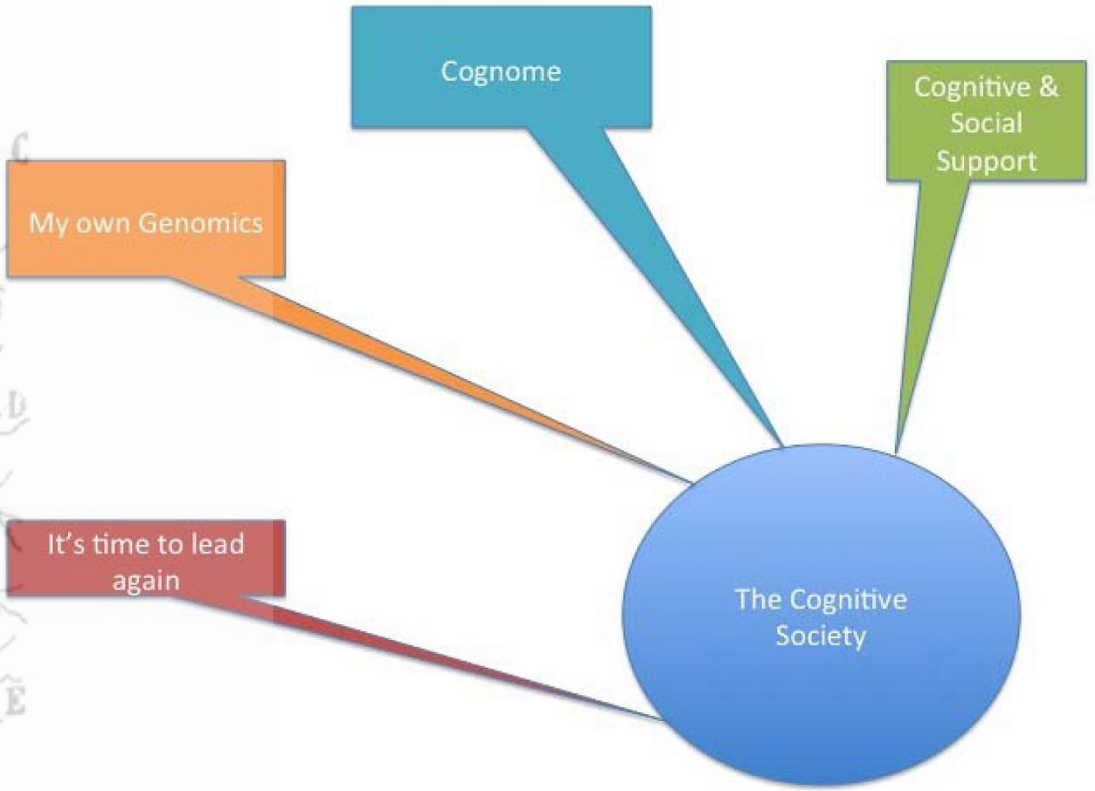
- Prime the pipeline w. the right kind of folks
  - What is a *transdisciplinary* scientist?
  - Enhance *Team Science* approaches
- Develop the tools understanding the cognome
  - Noninvasive brain imaging matched to neural code
  - *Big Data*
  - Interacting w. ensembles of neurons
- Governance structures
  - Data sharing/E-science

R&D Strategies:

- White House Brain Activity Map Initiative
- The gap: Between NIH and NSF funding coverage
- Fix P&T to incentivize trans-disciplinary
- Stakeholders (e.g. aging society) need to be properly involved
- Metrics of success standardized across disciplines
- Governance critical
- Invest in a new "Science of the Mind"
- Establish a *convergence* Ecosystem
- X-Prize Competitions

Conclusions and priorities:





Broad societal implications:

- Human society faces massive cognitive, communicative and physical challenges ahead
- Quality of human decision-making is fxn of natural human cognition and emergent effects of human-human interactions
- Welfare of human feeds back onto human cognitive capabilities and human decision making…

Broad societal implications (2):

- Thus: Convergent technologies that affect human cognition, communication and quality of life are of broad import!
- Our own view of what it means to be a human being will change fundamentally—a central characteristic of *The Cognitive Society*
  - BMI blurred
  - Human increasingly more deeply connected to each other
  - Notion of self evolves in yet unpredictable ways

The idea that our interacting cognitive brains represent an “information field” that can be explored using the same scientific principles that we have used to explore other fields may have a deep significance for how humans collaborate to solve complex problems in the future.